Evaluation of Aerobic Standards for Lunar Surface Extravehicular Activities

Nicole Strock, Ph.D.

Human Performance Scientist

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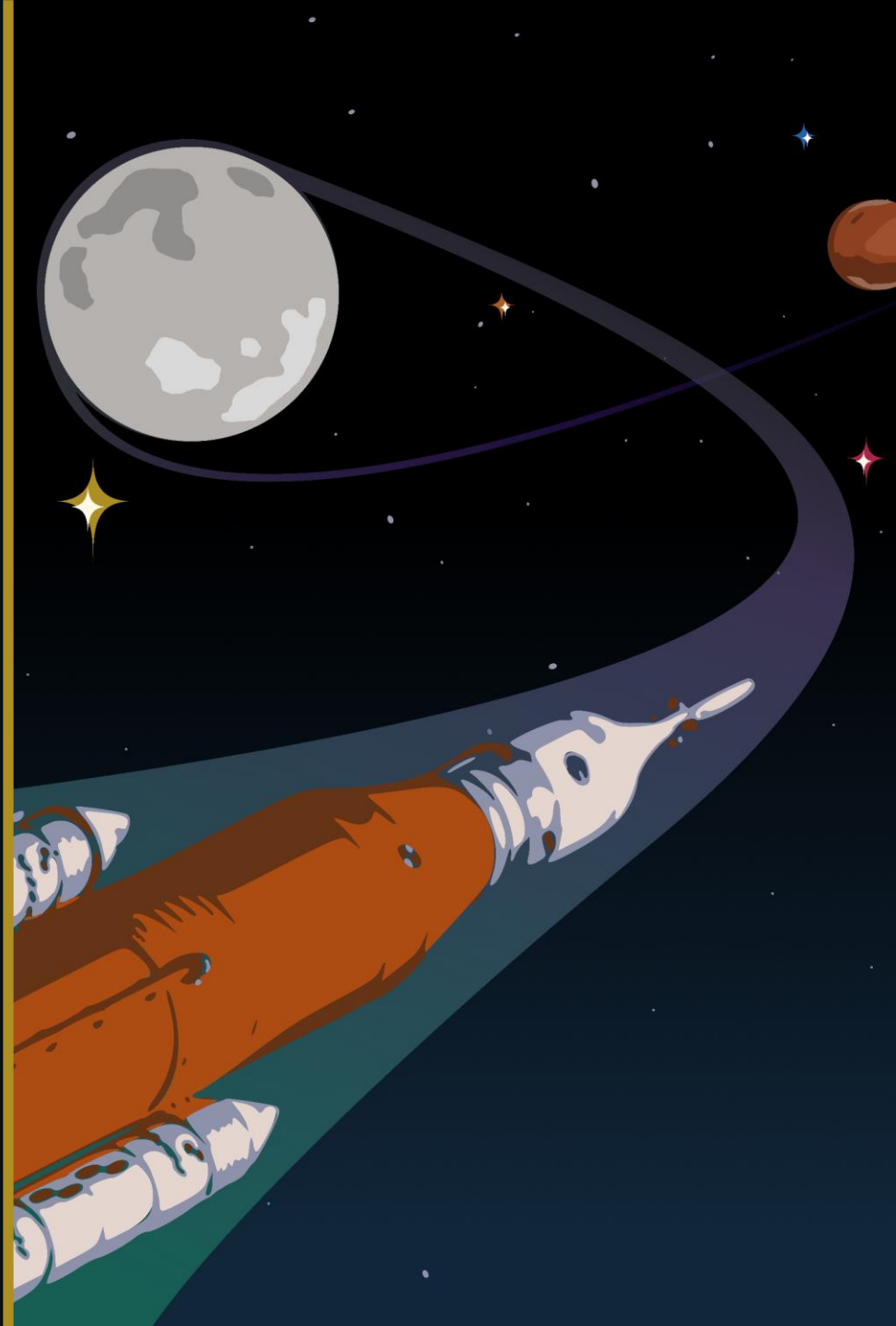
Considerations for Artemis Missions

- Greater physical demands than Apollo & current 0g ISS extravehicular activities (EVA)
  - ↑ Frequency
  - ↑ Intensity
  - ↑ Duration
  - ↑ Suit weight
- Sustainable work rates
  - 30-40% of aerobic capacity (VO_2peak)
- Suit limitations (9600 BTU/hr)
  - 1200 BTU/hr for 8 hr
  - 1600 BTU/hr for 6 hr
- Optimizing physical fitness is essential for safe & successful completion of mission tasks



Nicole Strock|
nicole.c.strock@nasa.gov

Analogs to inform Future Lunar EVAs

- Some data available from Apollo
  - Limitations: sparse, metabolic output measurements/ estimates, different suit

- Lunar analogs help provide estimate of metabolic demands for planned Lunar surface EVA-related tasks
  - Neutral Buoyancy Laboratory (NBL)
  - Active Response Gravity Offload System (ARGOS)

NASA 3001 Aerobic Fitness Standards

4.1.2 Celestial Surface EVA Aerobic Capacity

[V1 4002] Crewmembers **shall** maintain an in-mission maximum aerobic capacity (VO_{2max}) at or above 36.5 $ml \cdot min^{-1} \cdot kg^{-1}$ for missions with celestial surface EVAs as determined by either direct or indirect measures.

- Based on data from simulated mission critical tasks[a,b]
- Currently not validated, requires more research to evaluate applicability
- Appropriate thresholds for VO_2peak are key in determining optimal fitness for partial-g EVA success

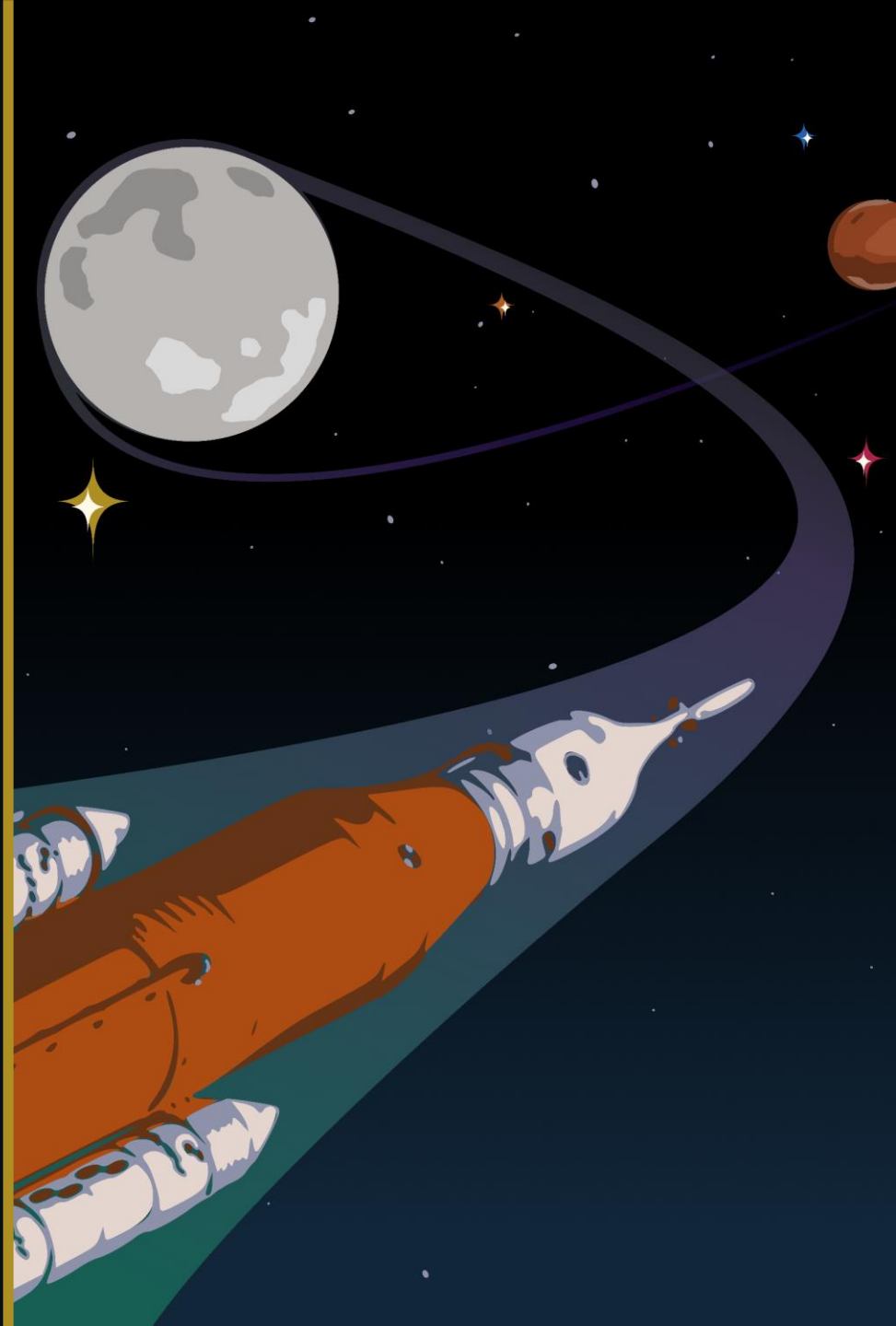
[a]Ryder Eur J Appl Physiol 2019 ; [b]Sutterfield MSSE 2019

Aims

1. Characterize relative metabolic data from Lunar analog simulations

2. Characterize in-flight crew VO_2peak data in relation to NASA 3001 celestial surface EVA standard

   (VO_2peak ≥36.5ml/kg/min).



Methods

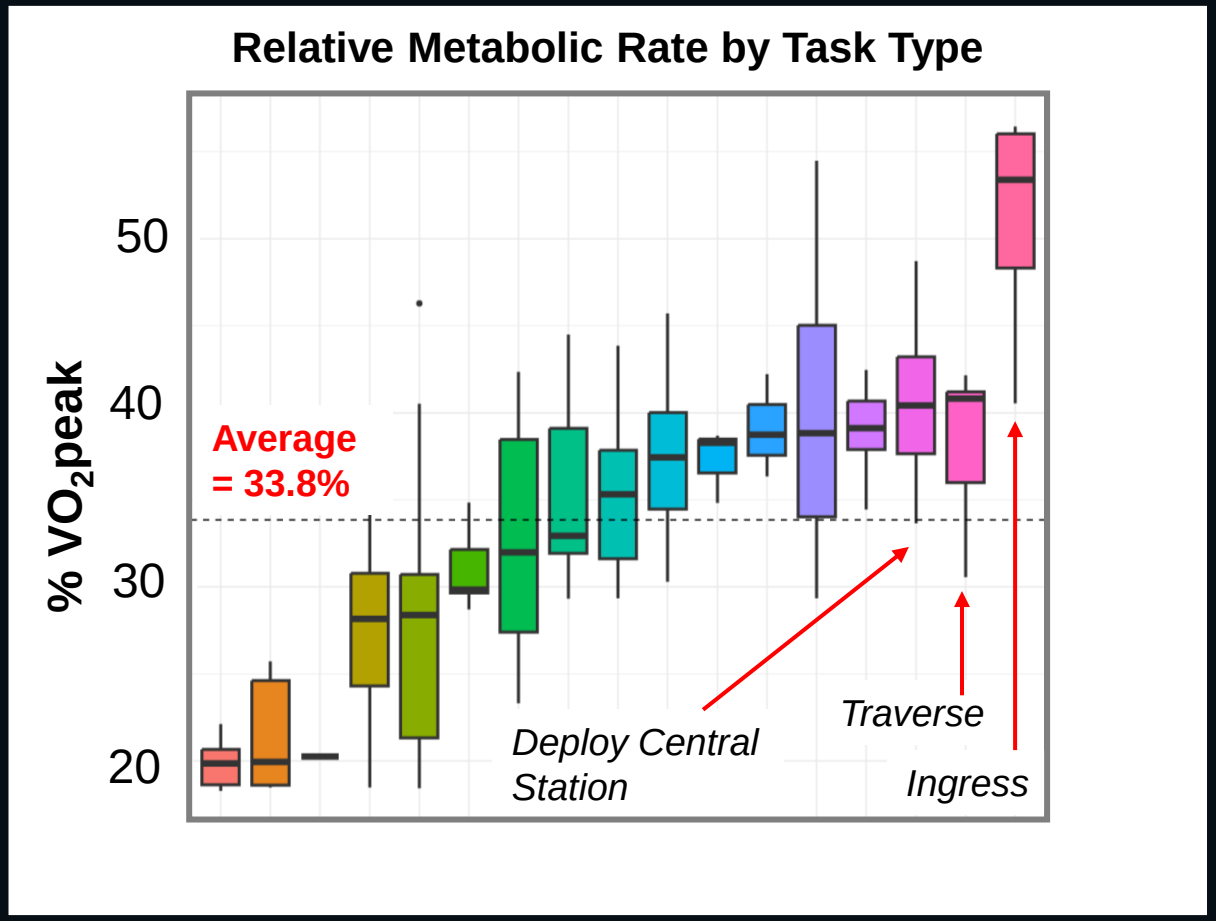
1. Analog Relative Metabolic Characterization

- Preliminary data analysis of long-duration (6hr) EVA analog simulations
  - NBL, n=1 female
  - ARGOS, n=1 male
- Metabolic work rates were characterized relative to maximal VO_2peak
- Range of tasks include: geological sampling, traverse, deploying experimental packages, flag ceremony, object relocation, egress/ingress

2. Crew VO_2peak characterization

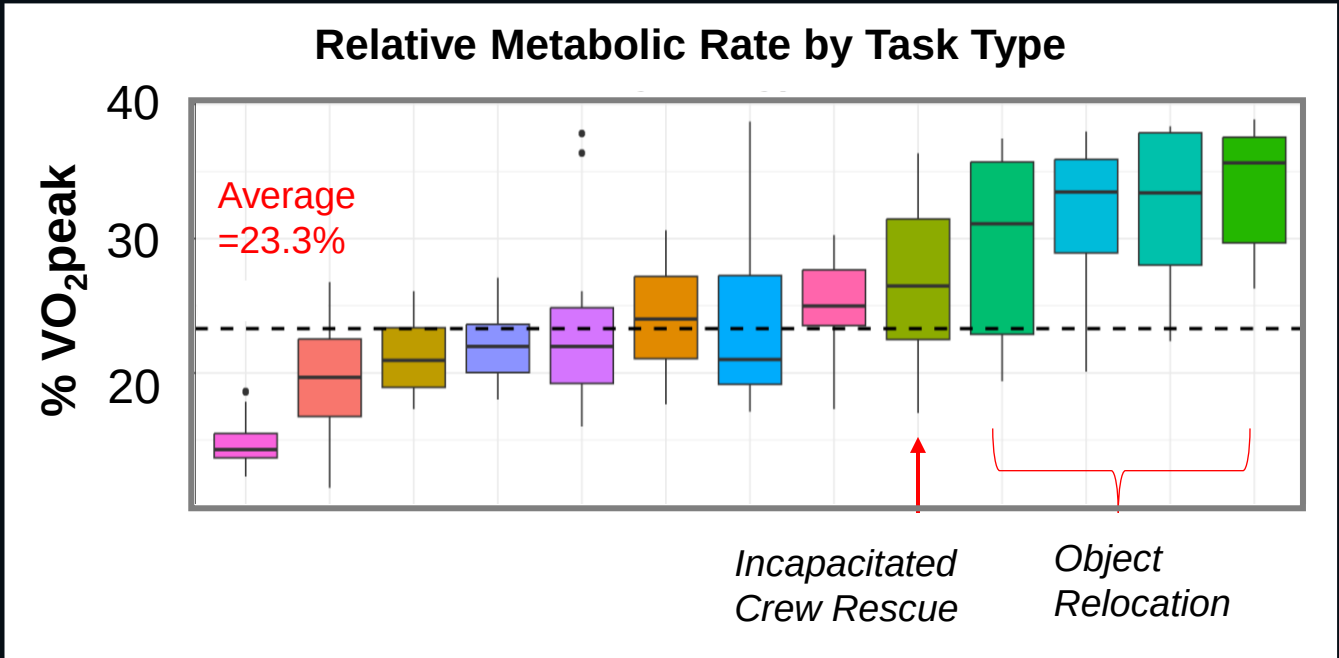
- ISS astronaut population (n=43; 30 M/13 F)
- VO_2peak measured before and during space flight (flight day 15)

Preliminary Findings: NBL Metabolic Rate Characterization



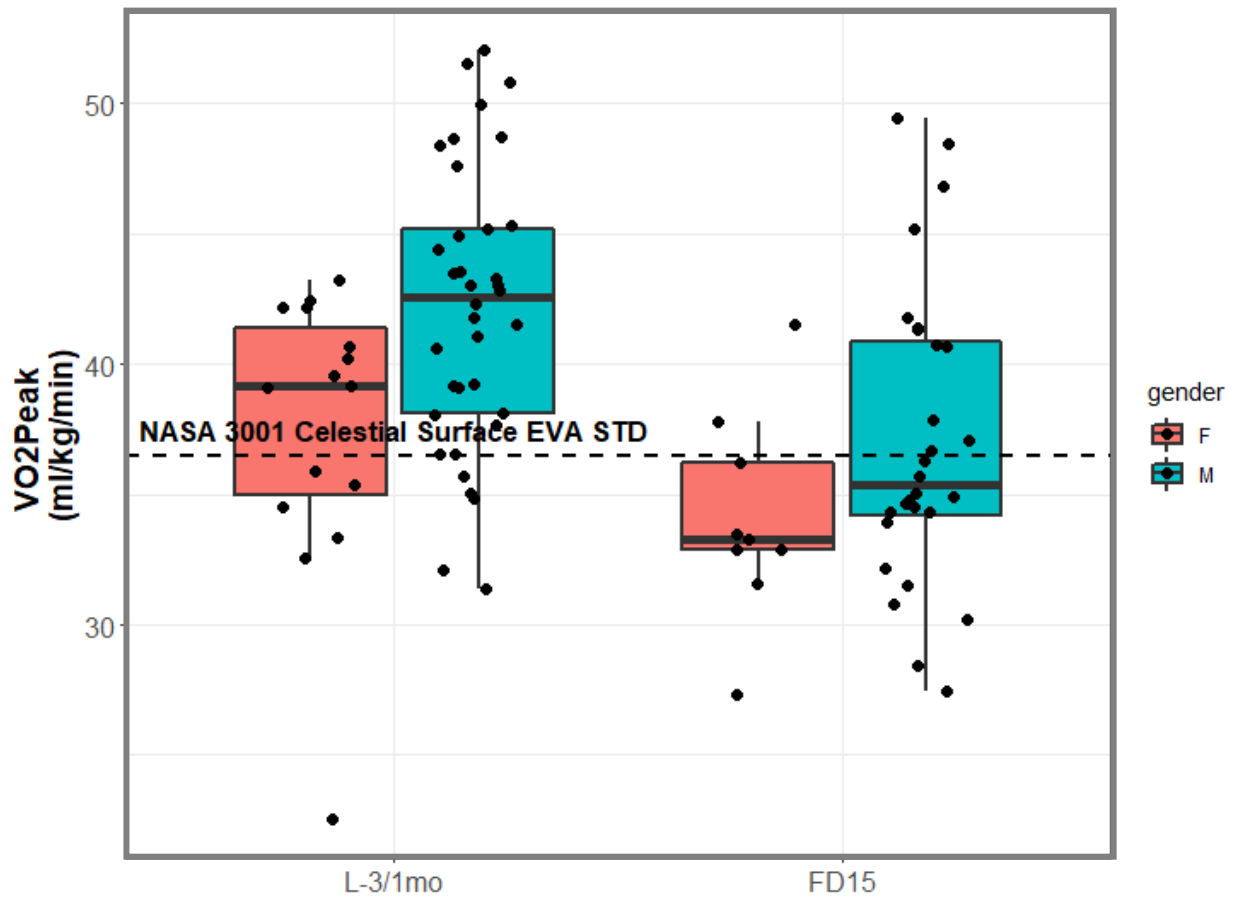
- Average 33.8% of VO_2peak
  - Within 30-40% sustainable work rate
- Tasks with highest metabolic demand (>40% of VO_2peak)
  - Ingress
  - Deploy central station
  - Traverse

Preliminary Findings: ARGOS Metabolic Rate Characterization



- Average 23.3% of VO_2peak
- Tasks with highest metabolic demand
  - Object Relocation
  - Incapacitated crew rescue

Preliminary Finding: Crew Aerobic Capacity



- In-flight reductions in VO_2peak
  - Females: 11.7%
  - Males: 10.9%
- Some crew do not meet NASA 3001 celestial EVA standard
  - Preflight: 21% fall below the aerobic capacity standard
  - In-flight: 62% fall below the aerobic capacity standard

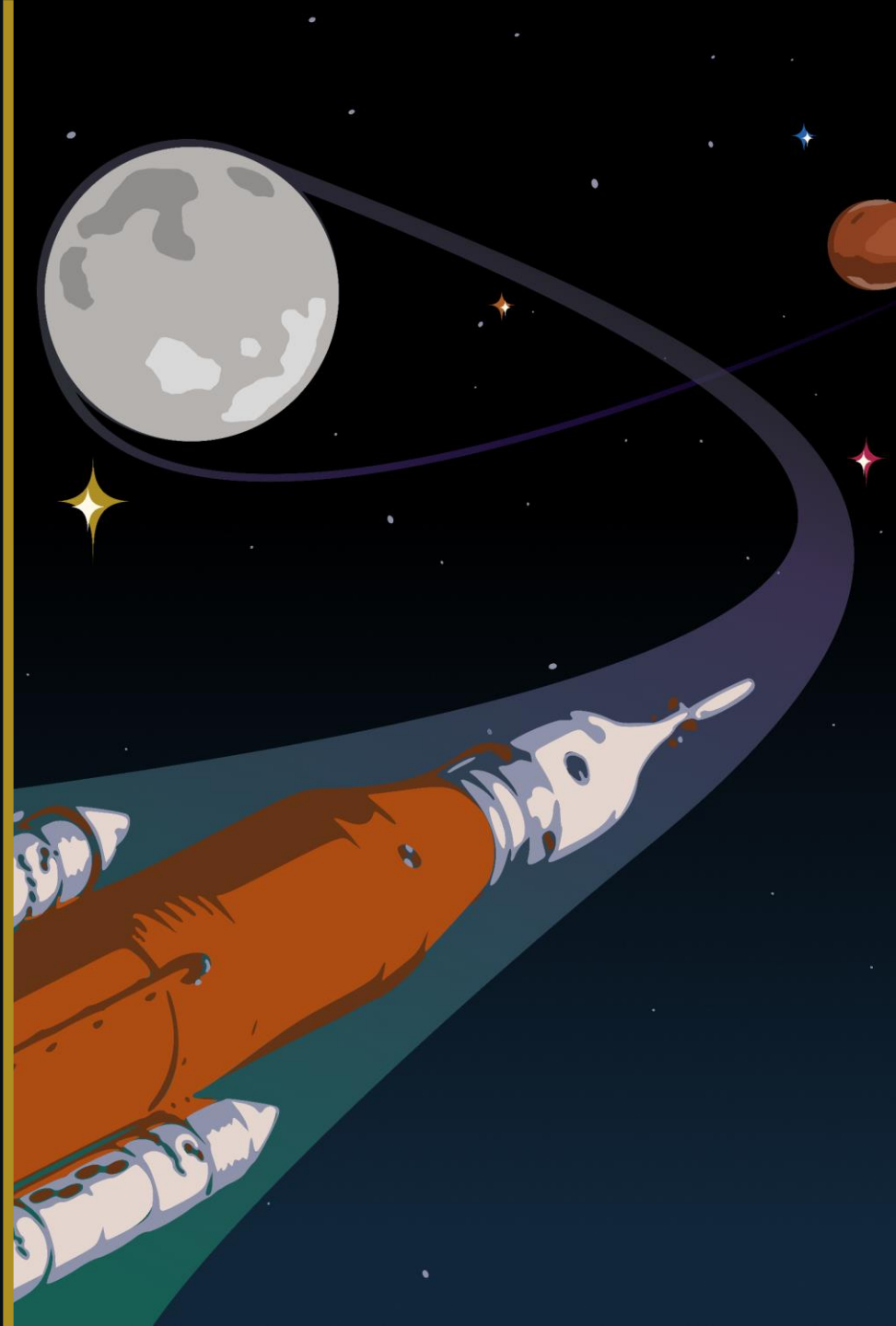
Future Directions

- Validate current NASA 3001 celestial EVA standards
- Develop future operationally relevant task performance thresholds
  - NBL/ARGOS runs with Artemis-specific task/tool utilization
    - Updated hardware and ConOps
  - Suited EVA task circuits performed at ranges of increased intensity
    - Evaluate relationship of fitness characteristics to task performance metrics (time to completion, # completed circuits, etc.)
  - Evaluate walking economy in series of graded conditions and speeds
    - Related to success of simulated suited runs?

Thank You!

- This is an ongoing effort that would not be possible without the following collaborators:

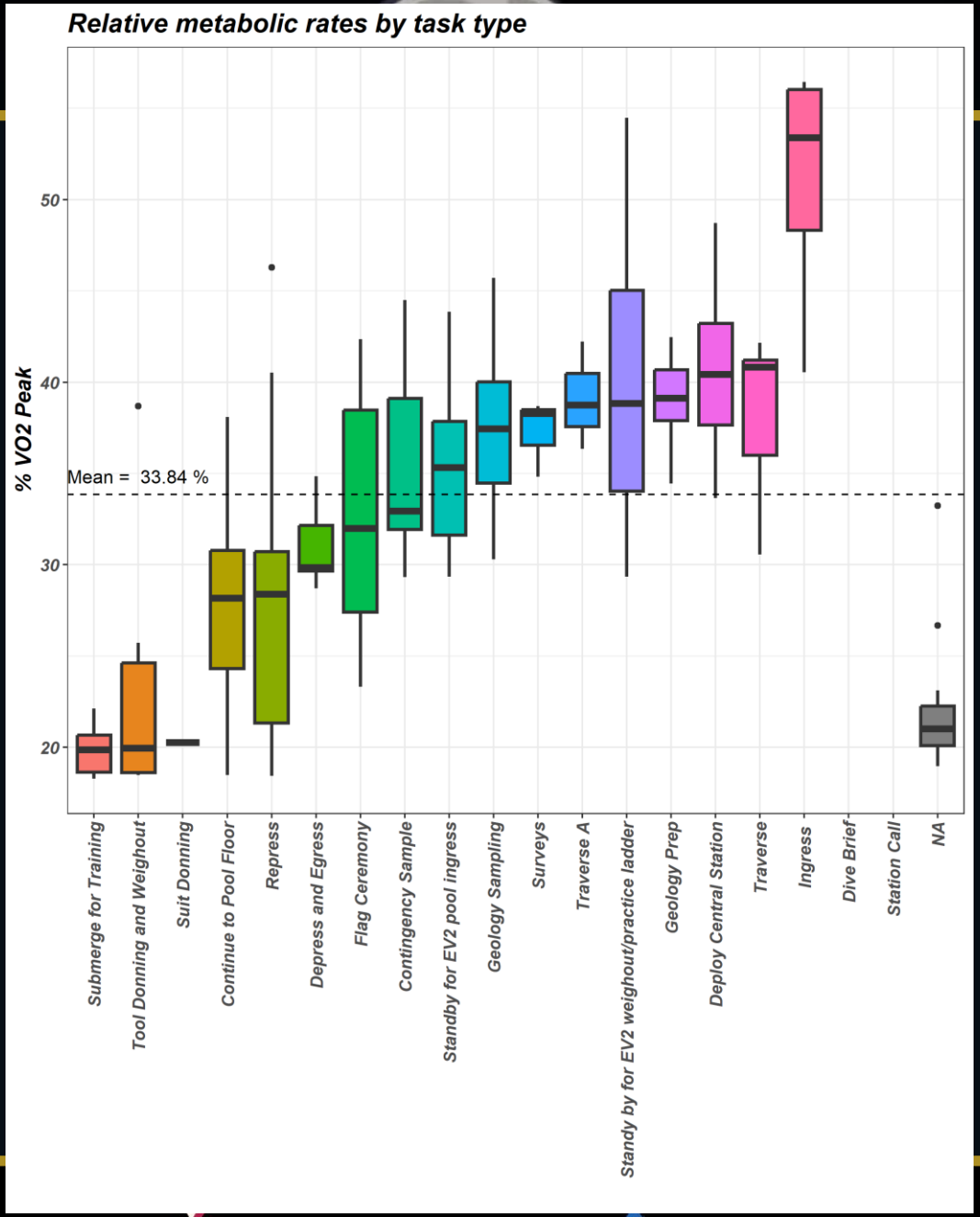
  - **Dillon Frisco**
  - **Lichar Dillon**
  - **Patrick Estep**
  - **Jason Norcross**
  - **Taylor Schlotman**
  - **Brian Prejean**
  - **Karina Marshall-Goebel**

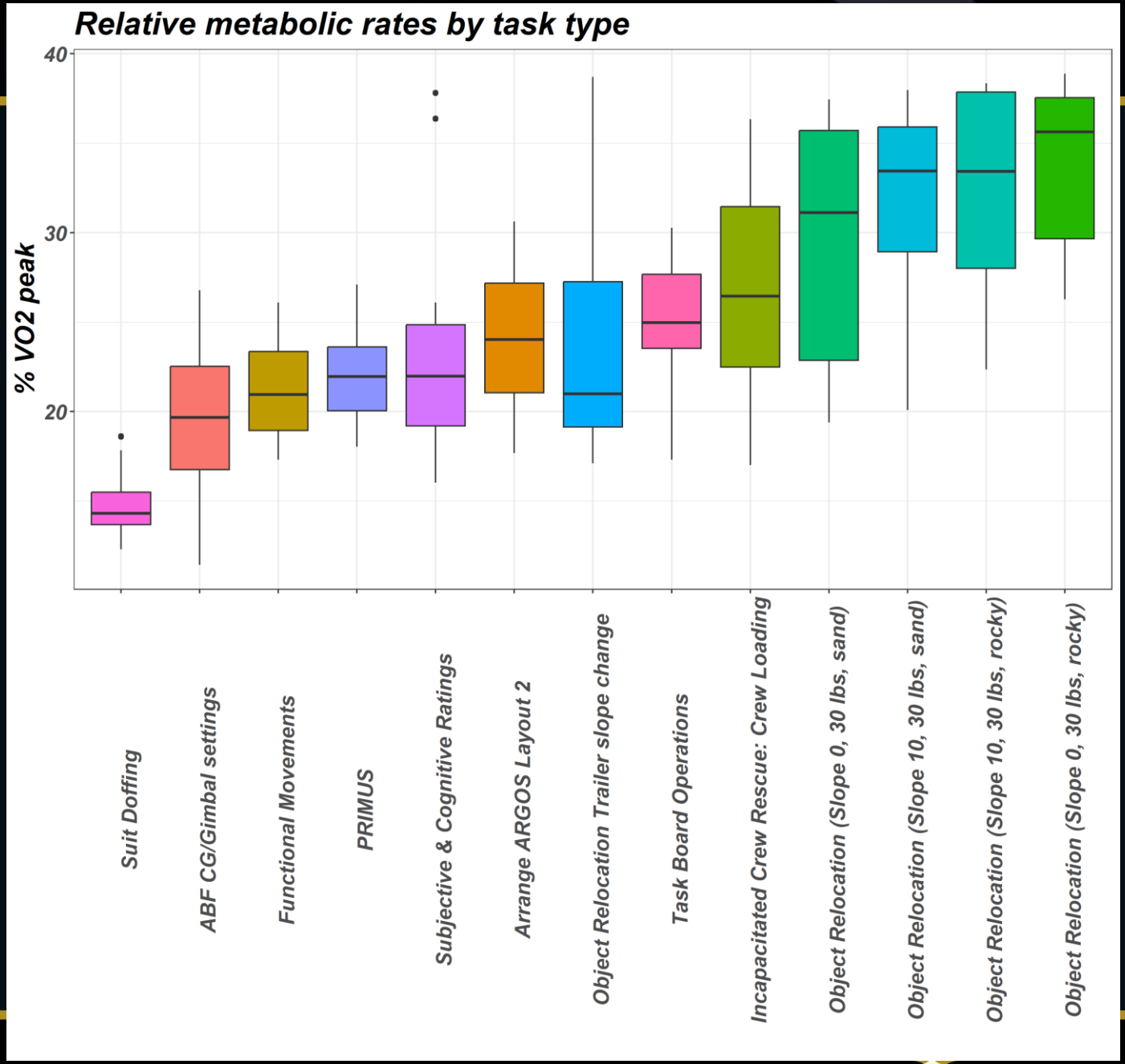


Thank You!

Questions?

Backup


Relative metabolic rates by task type
% VO2 Peak
Mean = 33.84 %
Submerge for Training
Tool Donning and Weighout
Suit Donning
Continue to Pool Floor
Repress
Depress and Egress
Flag Ceremony
Contingency Sample
Standby for EV2 pool ingress
Geology Sampling
Surveys
Traverse A
Standy by for EV2 weighout/practice ladder
Geology Prep
Deploy Central Station
Traverse
Ingress
Dive Brief
Station Call
NA


Relative metabolic rates by task type
% VO2 peak
Suit Doffing
ABF CG/Gimbal settings
Functional Movements
PRIMUS
Subjective & Cognitive Ratings
Arrange ARGOS Layout 2
Object Relocation Trailer slope change
Task Board Operations
Incapacitated Crew Rescue: Crew Loading
Object Relocation (Slope 0, 30 lbs, sand)
Object Relocation (Slope 10, 30 lbs, sand)
Object Relocation (Slope 10, 30 lbs, rocky)
Object Relocation (Slope 0, 30 lbs, rocky)